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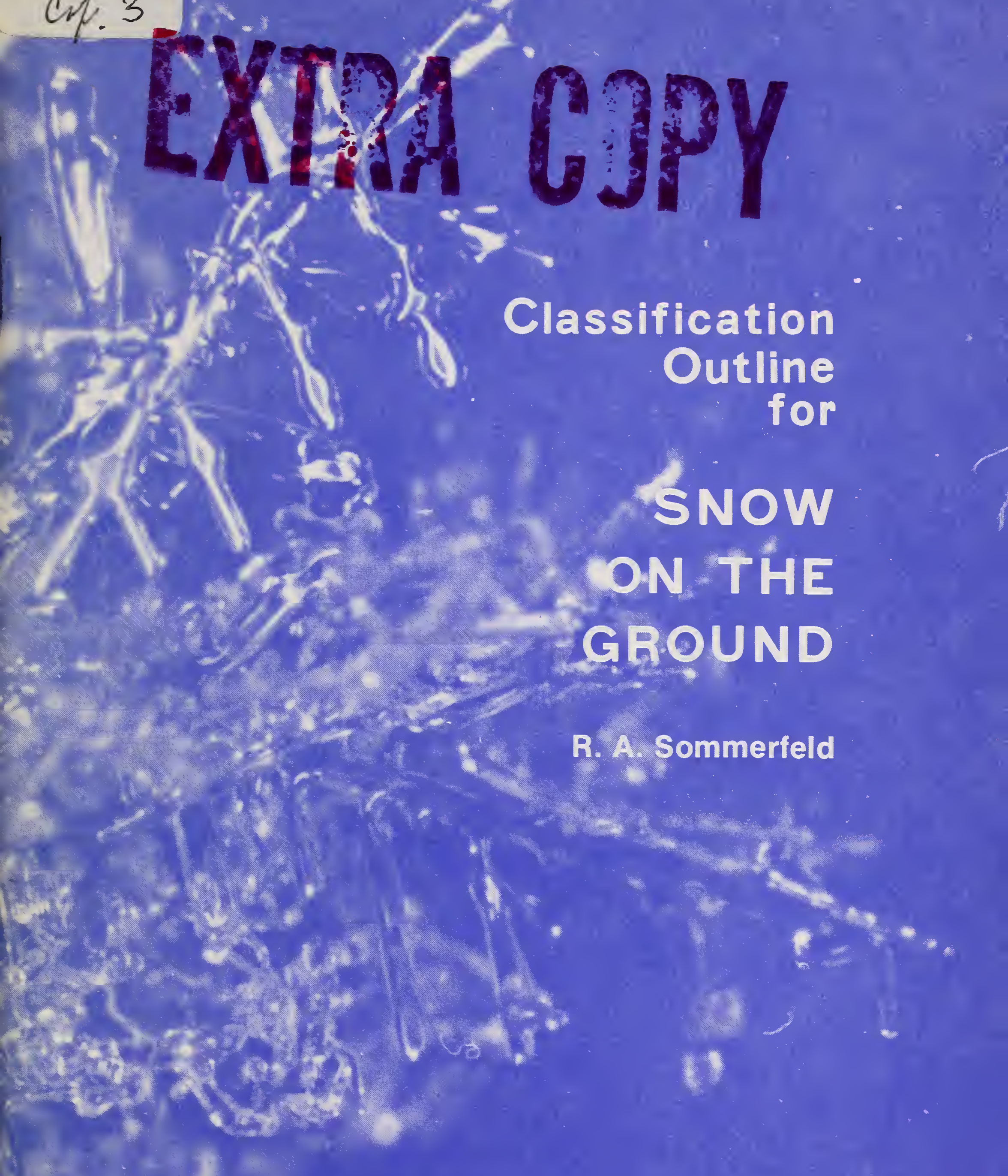

Classification Outline for SNOW ON THE GROUND

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—About the cover:

Stage II.A.1. The beginning of equi-temperature metamorphism when the original snow crystals begin to lose their fine detail.

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by

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[1]Central headquarters maintained at Fort Collins in cooperation with Colorado State University.

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Definitions

Terms which are commonly used in snow research are listed here with their definitions. We hope that by defining these terms we will avoid the confusion which has resulted from their misuse.

Angular grain:
A grain with facets which are separated by sharp corners.

Crystal:
Any substance, usually solid, whose atoms or molecules are arranged in an orderly array.

Cup crystal:
A snow grain with a roughly pyramidal shape and a roughly hexagonal cross section. The surfaces of cup crystals are usually deeply stepped. The cups may be filled or hollow.

Deposition:
The direct formation of ice from the vapor phase. The opposite of sublimation.

Facet:
A plane or flat surface on a grain. These are usually external manifestations of the internal order of a crystal.

Form:

The external shape of a crystal, which may or may not reflect its internal order.

Grain:

The obvious subunit in snow on the ground. In snow research, this term does not have the same meaning as the term in metalography.

Lattice grain:

A grain of irregular form with pronounced stepped surfaces.

Neck:

The narrow interconnections between grains or parts of grains.

Phase:

A system that is uniform throughout, both in chemical composition and physical state (neglecting the effects of surface energy).

Pore:

The spaces in a solid material which are not occupied by a solid. These may interconnect so that a fluid can pass through a sample of the material, or they can be noncommunicating so that the material is impervious to fluids.

Precipitation:

Liquid or solid water that falls from the atmosphere to the ground.

Snow crystal:

A single crystal of ice, usually of complex form, which grows by vapor deposition in the atmosphere.

Snowflake:

A polycrystal of airborne snow. An agglomerate of snow crystals.

Structure:

1. The arrangement of atoms in a crystal.

2. The layering or stratigraphy of a snow cover. Because of the vast difference in scale, there should be no confusion over the two meanings.

Sublimation:

The process of vapor forming directly from a solid. The opposite of deposition.

Surface energy:

The energy required to form a certain amount of new surface, for example between ice and air.

Texture:

The relationships among snow grains or crystals in a snow cover.

Discussion

Previous classification schemes for deposited snow have been based primarily on the forms of the snow grains. Such a basis was necessary when little was known about the processes which occur during the metamorphism of a snow cover. Recent work has outlined the important processes and their relationships to the various forms, so that it is now possible to develop a classification scheme based on physical processes. Since these processes are directly related to the

changes in the physical properties of a snow cover, such a classification scheme will be more useful in evaluating these properties. Also, by systematizing the processes, a better understanding of their relationships can be gained and areas where more work is needed will be made apparent.

In the following classification for snow on the ground, we have separated and idealized the important processes in snow metamorphism. Snow found in nature will undergo some mixture of the processes listed, and its history could be summarized by a series of classifications. Words to be found in the list of definitions are in bold type. The illustrations that follow are keyed into the classification system.

Classification

I. UNMETAMORPHOSED

The major process that affects snow as it **precipitates** is mechanical breakage under wind action.

A. No wind action

Since this snow is not strongly affected by any process, there is little difference between it and snow in the air. We recommend, therefore, that it be classified in accordance with the system of Magono and Lee (1966).

B. Wind blown

Snow in this classification contains very few, if any, whole **snow crystals**. Parts of the original

forms may be recognizable, or the process may have proceeded to the point that no forms can be recognized. We also recommend the system of Magono and Lee (1966) for this category.

C. Surface hoar

The deposition of water vapor directly on the surface without precipitation. The forms are similar to those developed under III B (below) except that flat plates are much more common, and there is no pronounced three-dimensional development.

II. EQUI-TEMPERATURE METAMORPHISM

The process that distinguishes this category is the transport of water vapor from regions of high surface energy to regions of lower surface energy in a snow cover which has a constant, below freezing, temperature throughout. This process leads to the destruction of the original forms and to the production of uniform, fairly well-rounded grains.

A. Decreasing grain size

The destruction of sharp corners, the pinching off of necks, and the thickening of plates while their major diameter decreases, leads to a decrease in apparent grain size.

1. Beginning

Many of the original snow crystal shapes are recognizable but sharp corners have been rounded and most of the fine structure of the snow crystals has disappeared.

2. Advanced

A very few indistinct plates or snow crystal fragments may be recognizable, but the grains show distinct rounding.

B. Increasing grain size

For grains of the same shape, the smaller the size the larger the ratio of surface area to mass. Therefore, surface energy decreases further as the smaller grains disappear and the larger grains grow. This leads to an increase in average grain size and a decrease in grain number.

1. Beginning

No original snow crystal forms may be recognized. The grains show a definite equidimensional tendency. A few, indistinct facets may be visible.

2. Advanced

Larger, more equi-dimensional grains characterize this snow. There is a strong tendency toward uniform grain size, and faceting is generally absent.

III. TEMPERATURE-GRADIENT METAMORPHISM

Under a strong temperature gradient, water vapor is transported from the warmer (lower) to the colder (upper) layers by sublimation and deposition.

The relatively rapid transport of water vapor causes the lower portions of each **grain** to be in a supersaturated environment while the upper portions are in an undersaturated environment. The water vapor **sublimates** from the tops of the **grains** and **deposits** on the bottoms of **grains** above. The final result is well-oriented **grains** whose **form** reflects the temperature and vapor pressure gradients. Stepped surfaces, which are a known feature of rapid growth from the vapor, characterize most of the snow in this category.

A. Early

The result of a strong thermal gradient on new-fallen snow, usually associated with the first snowfalls of the season. Since the starting material has a large number of small **grains**, the very large, well-developed **cups** and **lattice grains** will not form.

1. Beginning

Angular and **faceted grains** are common, but stepped surfaces are very uncommon.

2. Partial

Medium-size **angular grains** predominate. Poorly formed steps are commonly found.

3. Advanced

Medium to large **angular grains** predominate, with well-developed **facets** and stepped surfaces. A few filled **cups** or an occasional hollow **cup** may be found.

B. Late

The result of a strong thermal gradient acting on snow in the later stages of metamorphism. Because the initial **grains** are relatively large and few in number, vapor transport produces larger, very well-developed **cups** and **lattice grains**. There may be some overlap with category III-A.

1. Beginning

Medium to large **angular** and **faceted grains** predominate. Fairly well-developed stepped surfaces are common.

2. Advanced

Large and very large **grains** predominate. Very fragile hollow **cups** and **lattice grains** with very well-developed stepped surfaces are common.

IV. FIRNIFICATION

Equi-temperature metamorphism leads to some densification of the snow cover. However, once the density has reached approximately that of randomly packed, uniform ice spheres (580-600 kg/m^3) further densification occurs through other processes. The two most important processes are melting and refreezing, and the reduction of **pore** space by relatively high pressure.

A. Melt-freeze metamorphism

When the snow temperature reaches the freezing point, either because of warm air temperatures or because of high solar radiation, the snow begins to melt and becomes a two-**phase** mixture. The melt water is trapped between the **grains**, filling some of the **pore** spaces. Refreezing then results in a denser snow cover. **Polycrystalline grains** characterize this sub-category.

1. Limited

The result of a single melt-freeze cycle with a limited gain in density. This causes thin ice layers and ice lenses in the snow cover when subsequent **precipitation** buries the layer.

2. Advanced

Repeated melt-freeze cycles result in an appreciable gain in density and an increased mechanical strength. The density range in this category is 600-700 kg/m^3.

B. Pressure metamorphism

The second important process in the densification of the snow cover is the reduction of **pore** space through action of pressure. This process is important in the formation of glacier ice from snow. **Polygranular crystals** are found almost exclusively in this sub-category.

1. Beginning

The grains are visibly deformed and rearranged by pressure. The pore space is reduced but is still communicating, and the density range is 700-800 kg/m^3.

2. Advanced

The grains are deformed and pressed together so that the pore space becomes noncommunicating (the permeability becomes zero). The density range is 800-830 kg/m^3.

Recommended Reading

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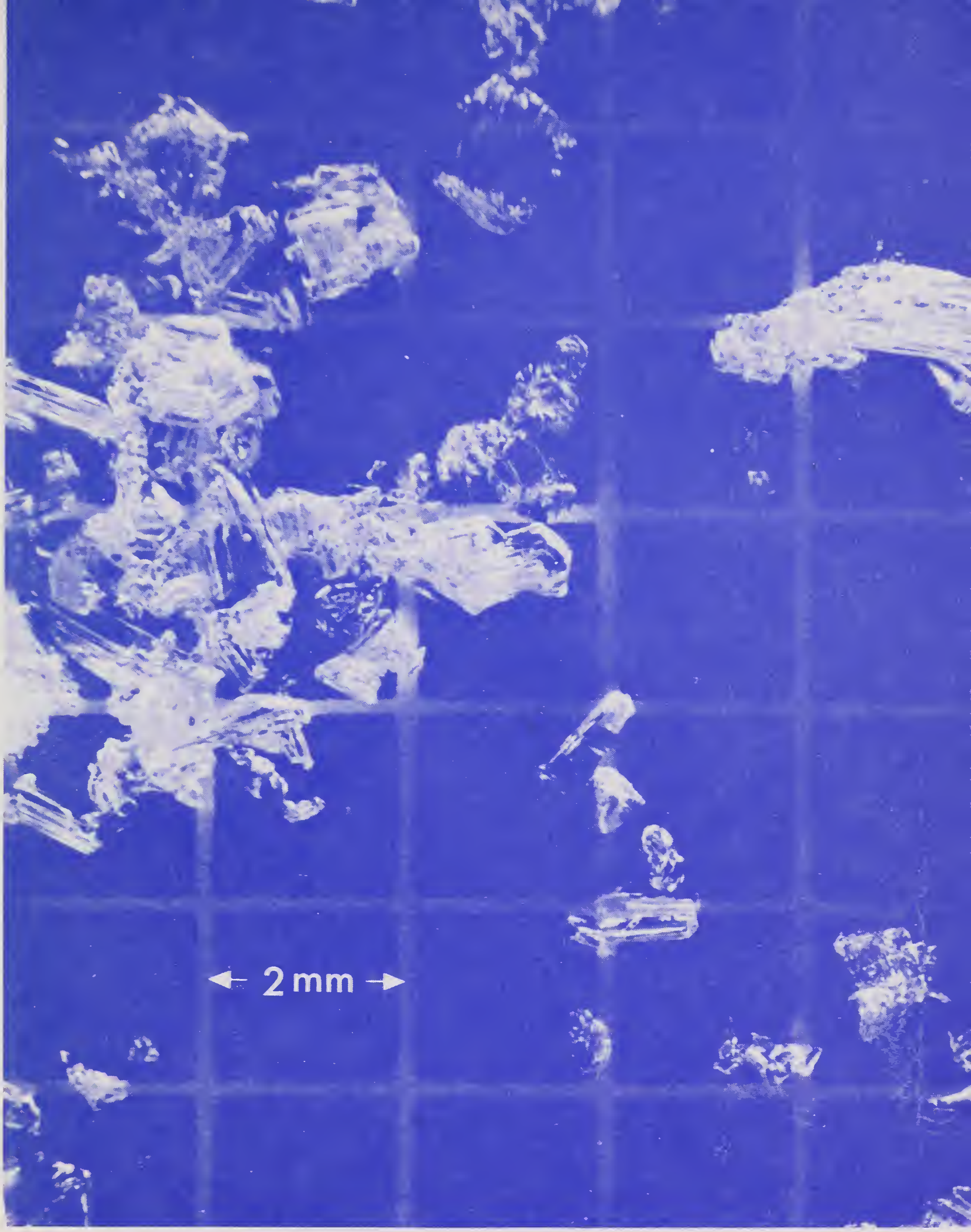
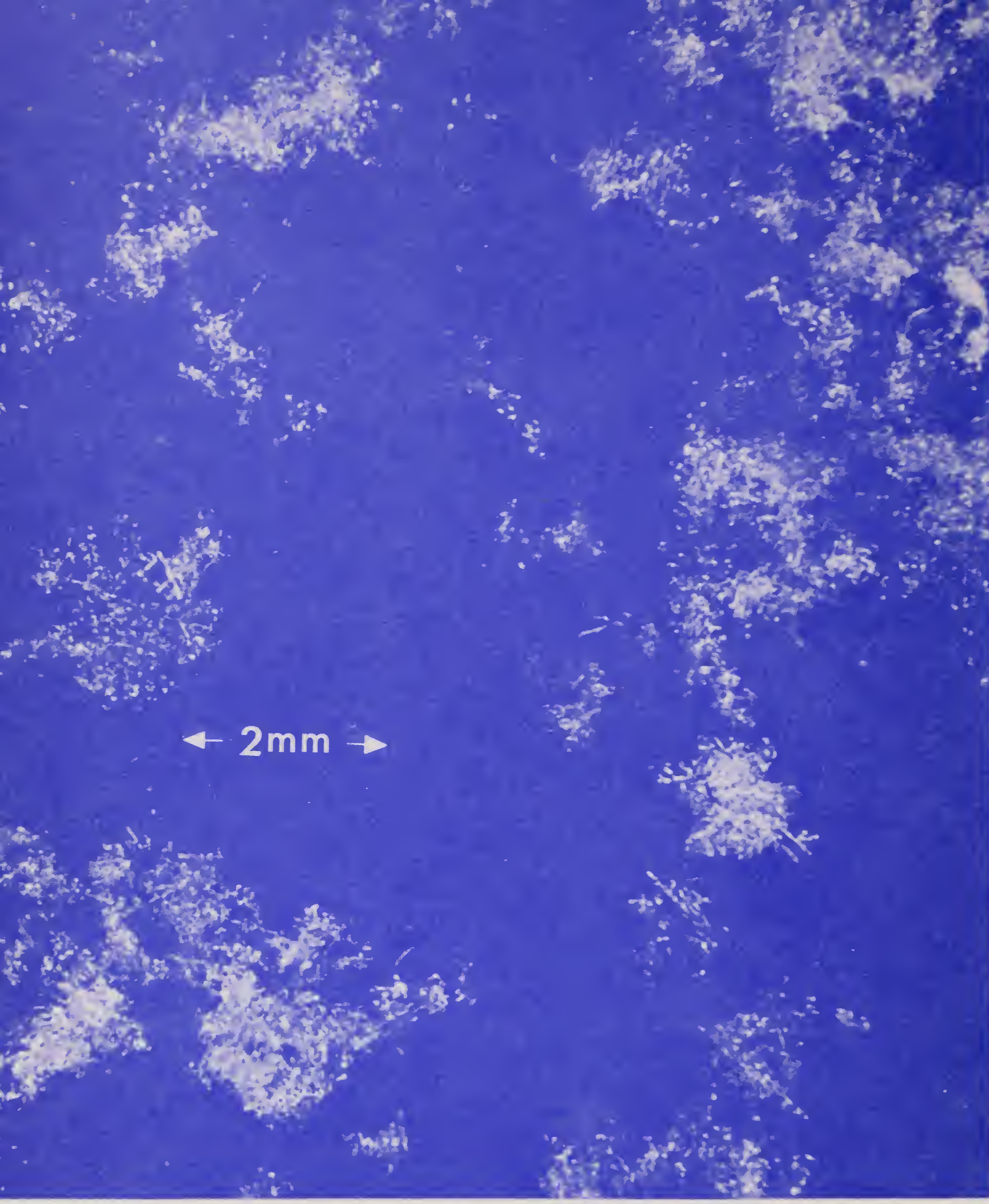
Magono, Choji, and Lee, Chung Woo
1966. Meteorological classification of natural snow crystals. J. Fac. Sci. Hokkaido Univ. Japan. Ser. VII. II(4): 321-335, 27 plates. (Reprinted by Alta Avalanche Study Center, U. S. D. A. Forest Serv., Wasatch National Forest, Salt Lake City, Utah, Sept. 1968.)

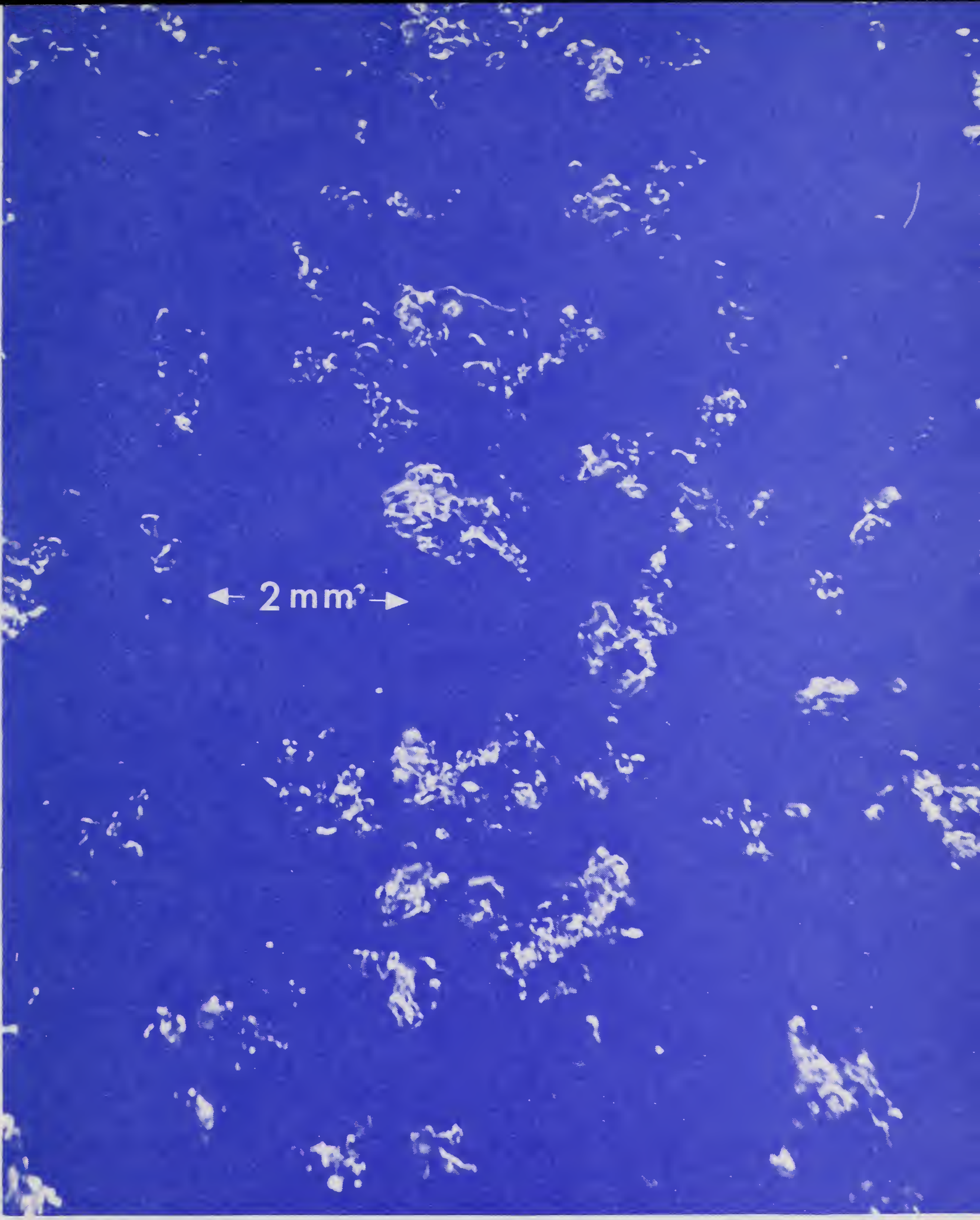
Wood, Elizabeth A.
1964. Crystals and light. Van Nostrand Momentum Book 5, 160 pp., illus. Princeton, N. J.: D. Van Nostrand Co., Inc.



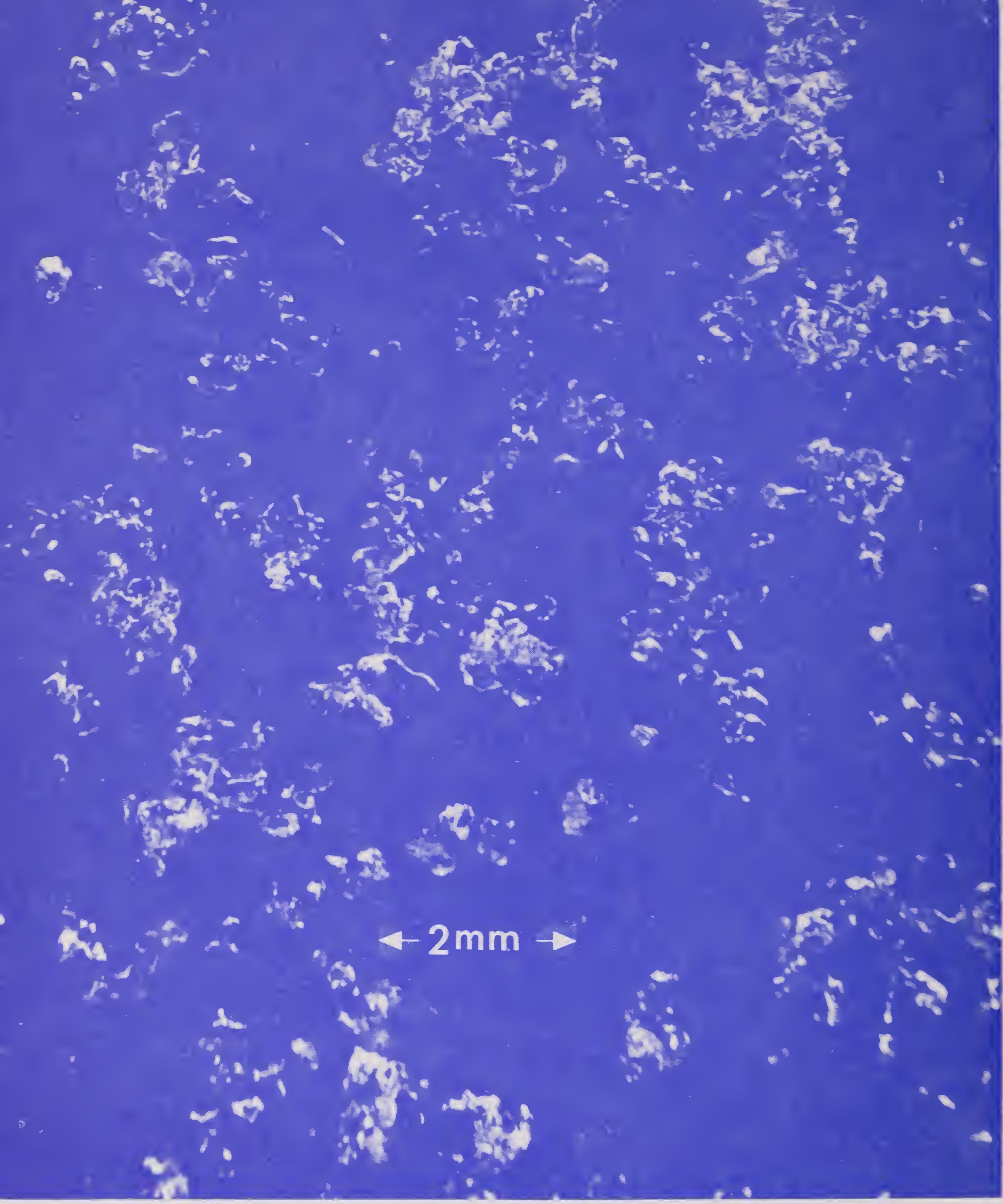
I.C. Surface hoar.



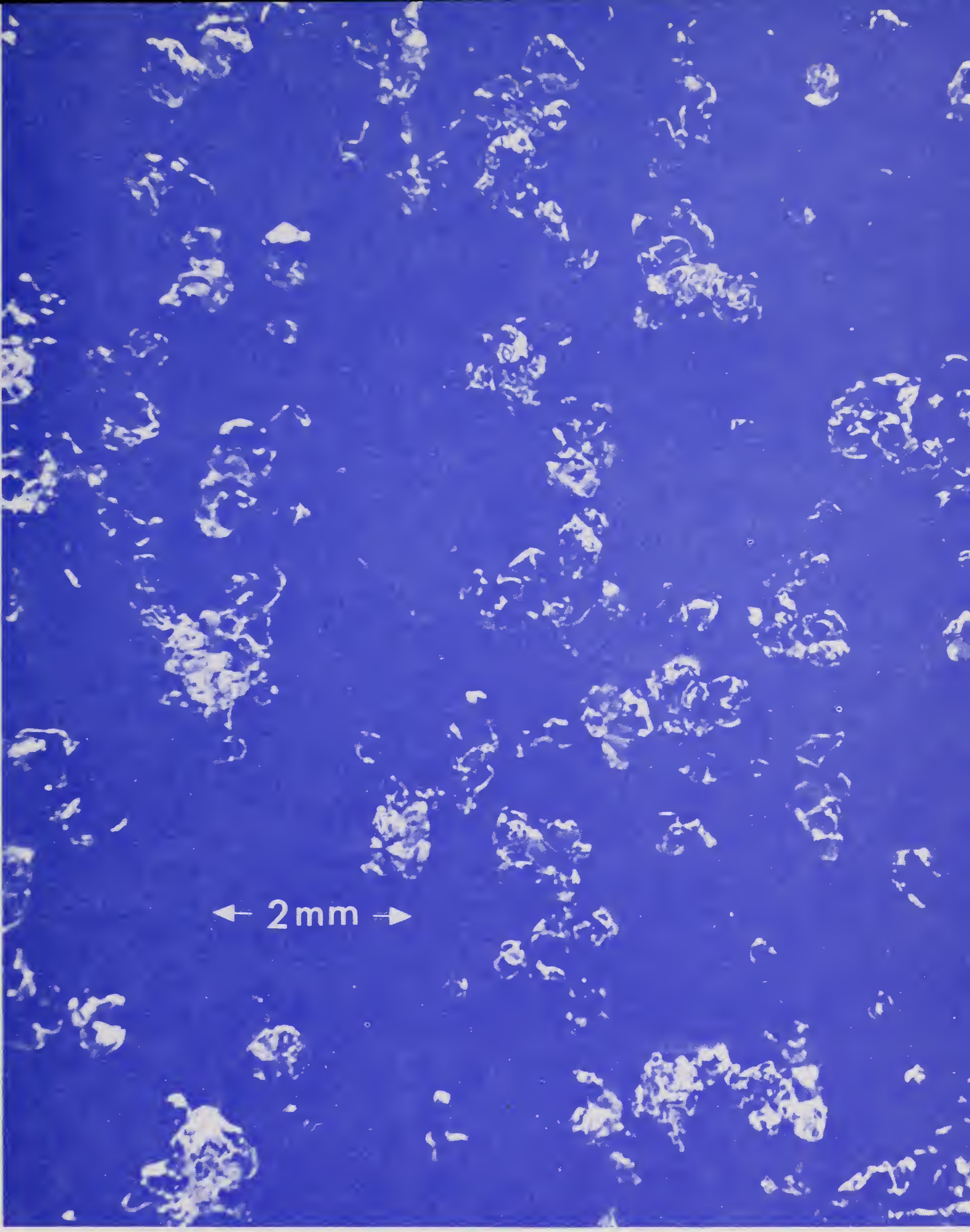
II.A.I. Beginning, decreasing grain size, equi-temperature metamorphism.



II.A.2. Advanced, decreasing grain size, equi-temperature metamorphism.



II.B.I. Beginning, increasing grain size, equi-temperature metamorphism.

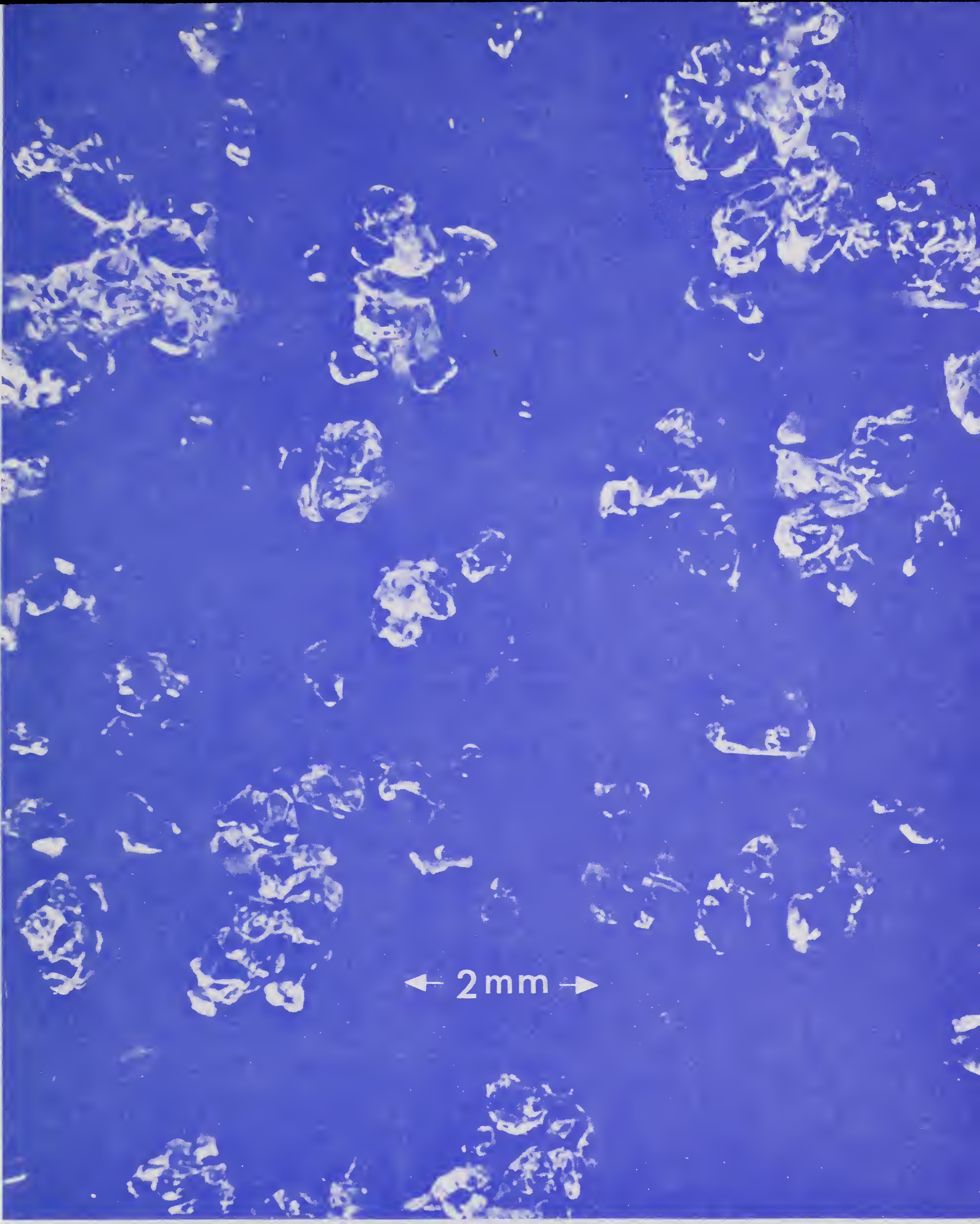


II.B.2. Advanced, increasing grain size, equi-temperature metamorphism.

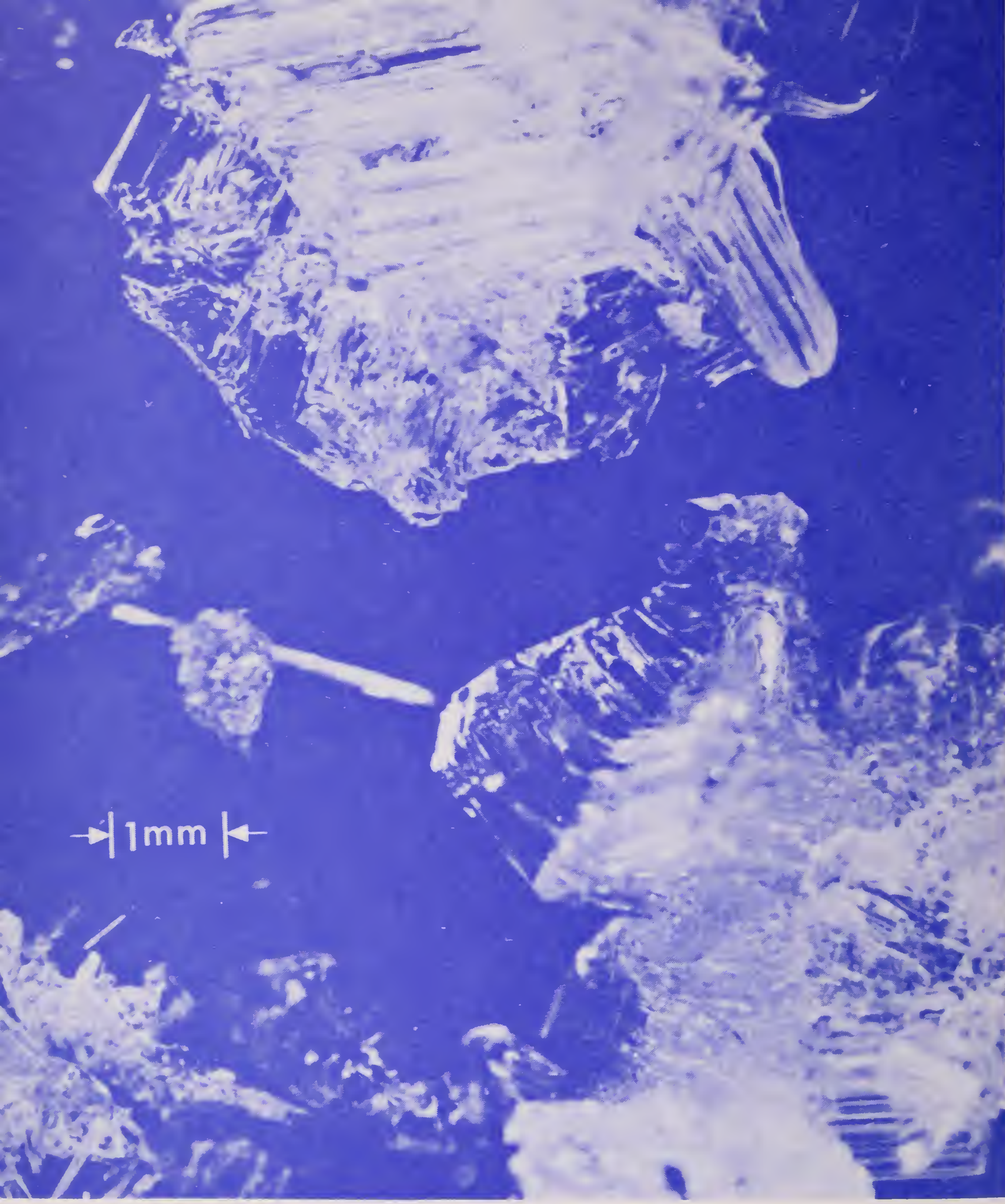
III.A.I. Beginning, early, temperature-gradient metamorphism.

III.A.2. Partial, early, temperature-gradient metamorphism.

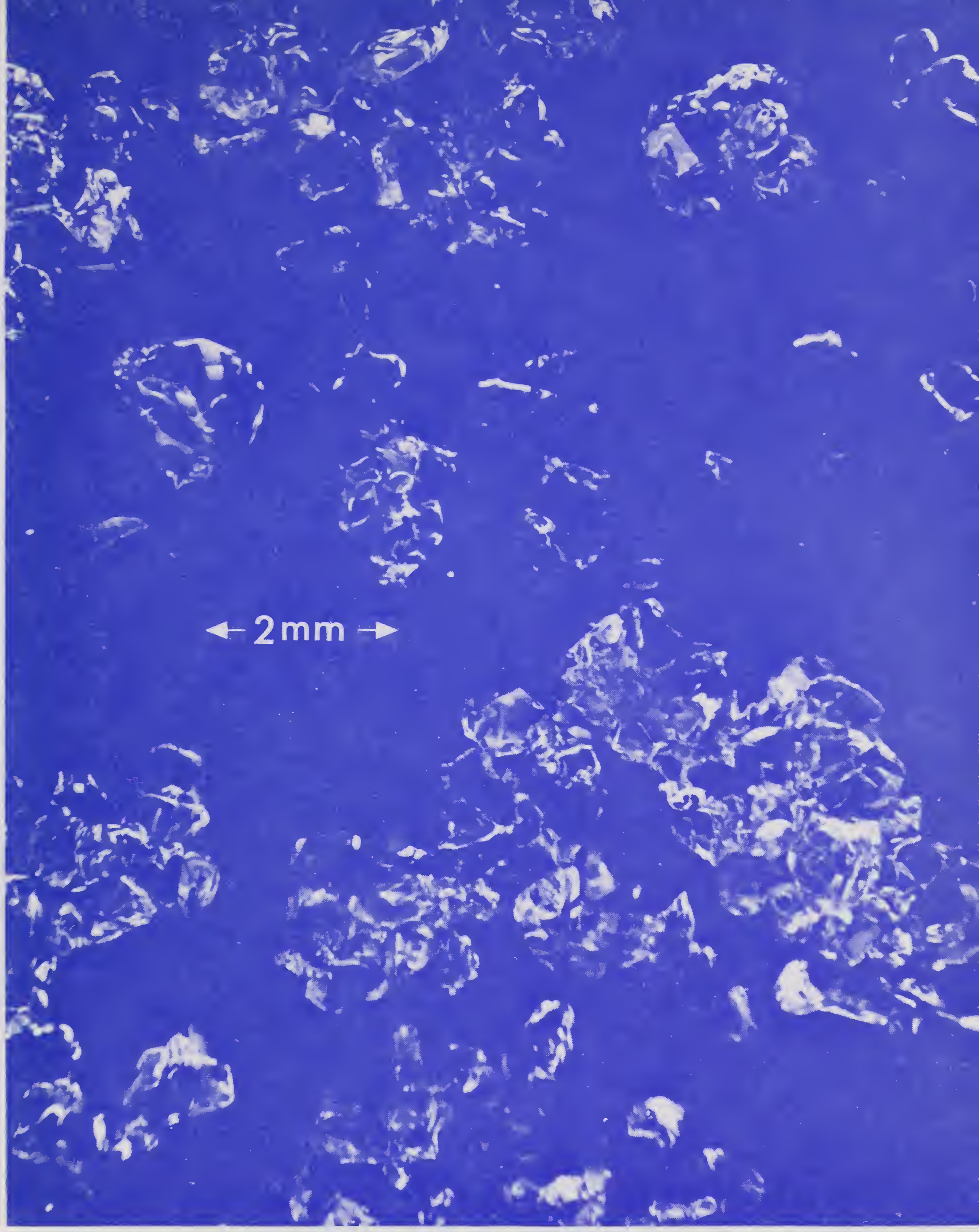
III.A.3. Advanced, early, temperature-gradient metamorphism.



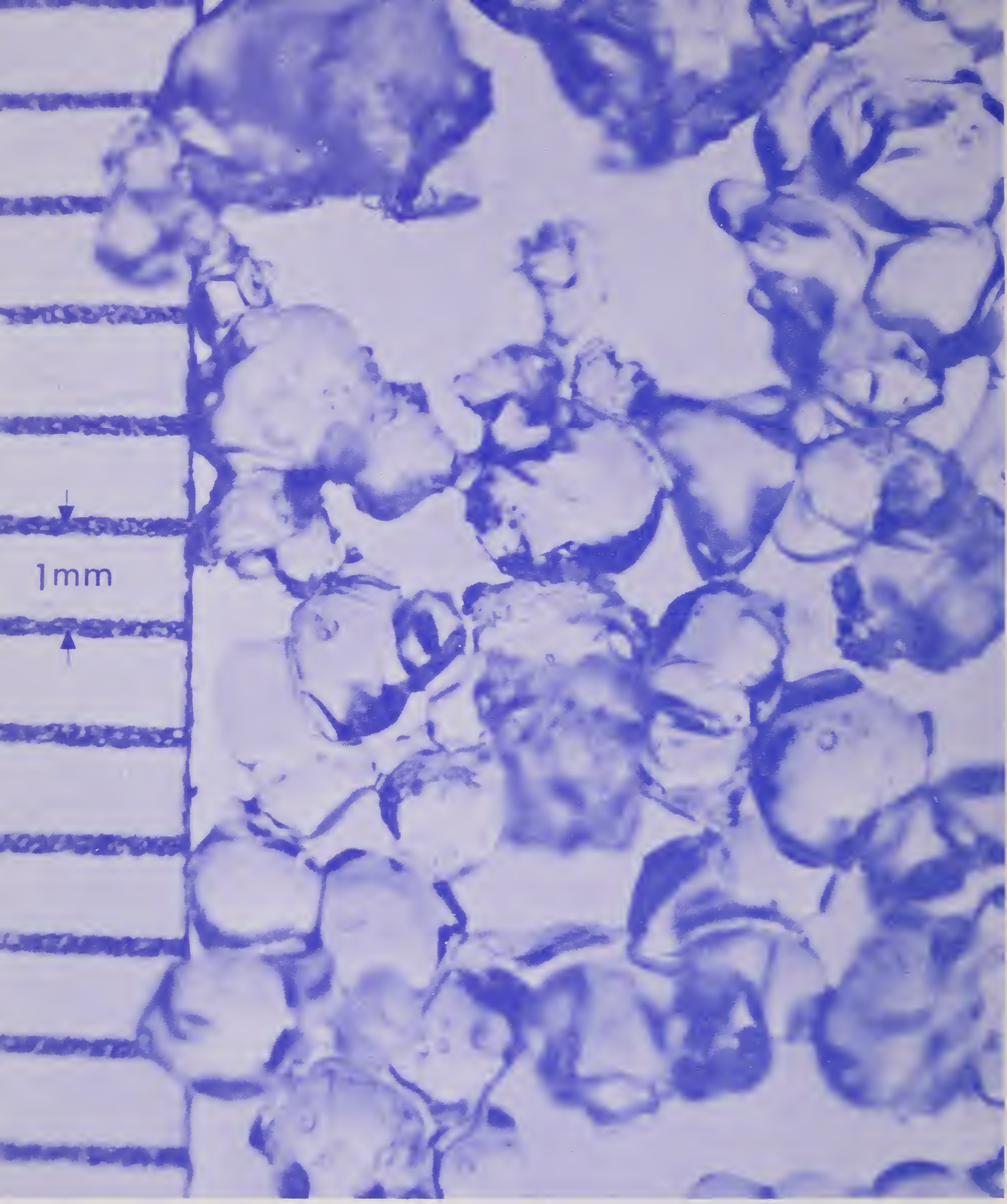
III.B.1. Beginning, late, temperature-gradient metamorphism.



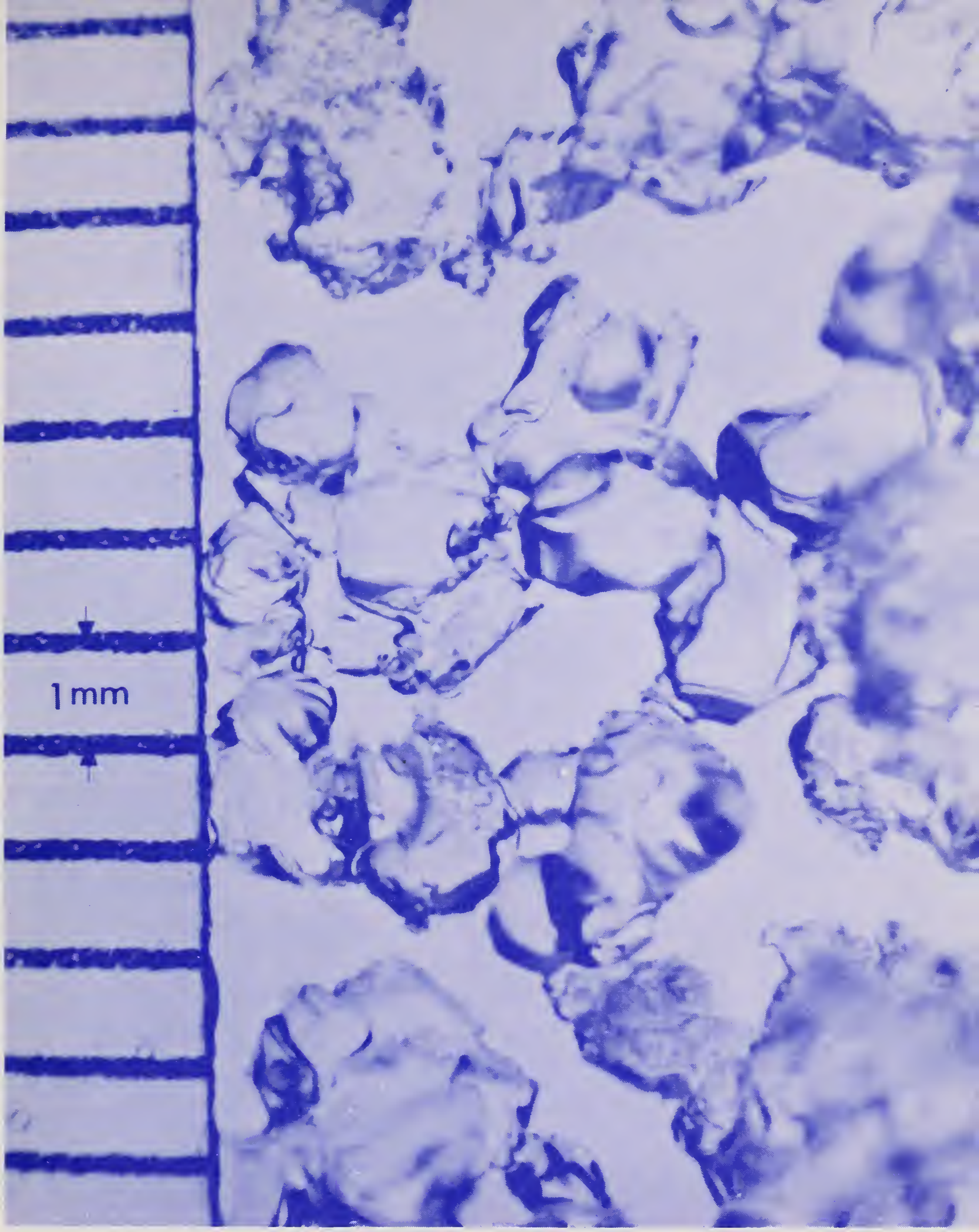
III.B.2. Advanced, late, temperature-gradient metamorphism.



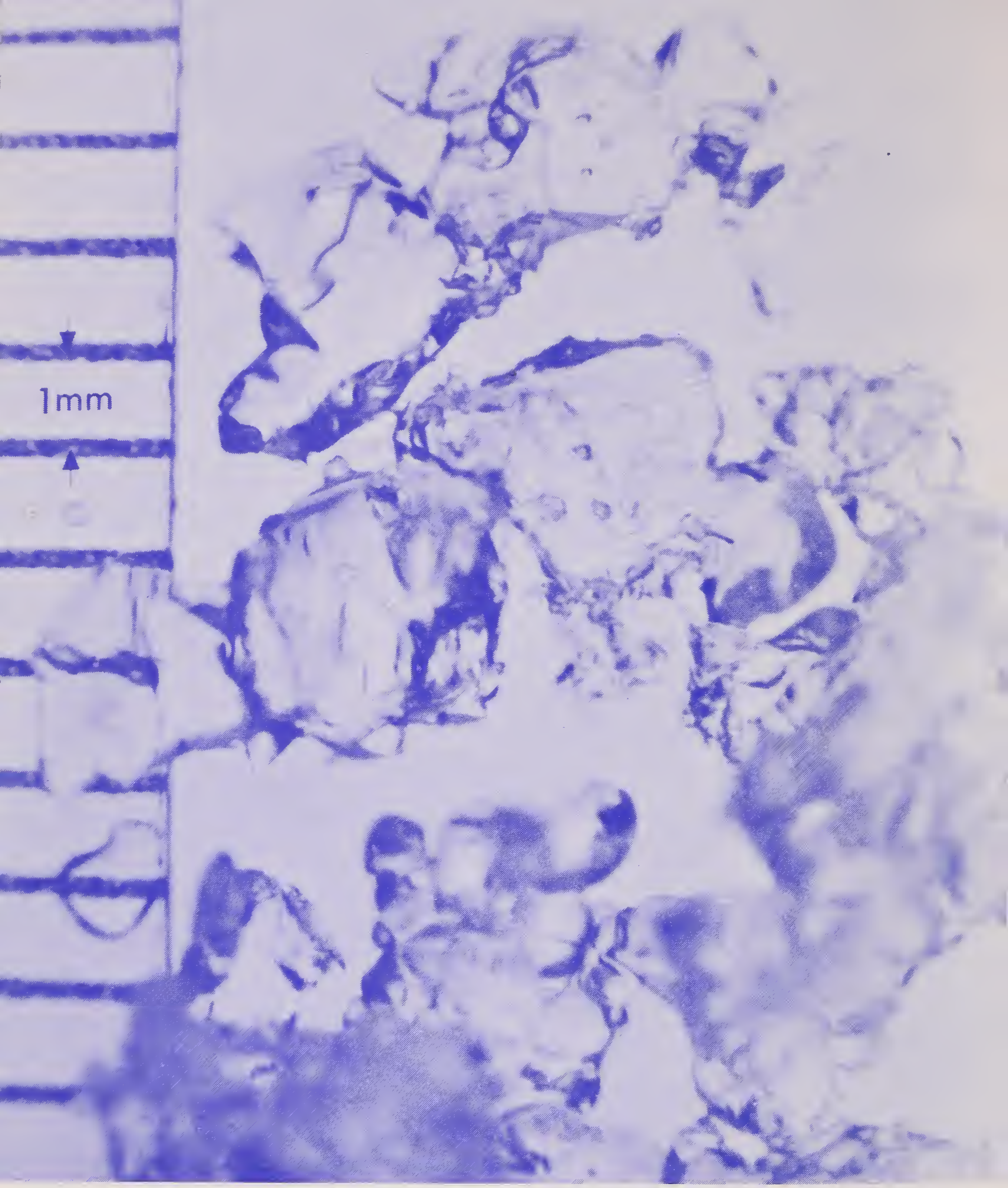
IV.A.1. Limited, melt-freeze metamorphism, firnification.



IV.A.2. Advanced, melt-freeze metamorphism, firnification.



IV.B.1. Beginning, pressure metamorphism, firnification.



IV.B.2. Advanced, pressure metamorphism, firnification.

Sommerfeld, R. A.
1969. Classification outline for snow on the ground. U.S.D.A. Forest Service Research Paper RM-48, 24 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.

A classification of snow on the ground is presented in outline form, with explanations and illustrations of the categories. The classification is based on the physical processes which result in various forms of snow particles. Thus it should be an aid in understanding the physical changes occurring as a snowpack metamorphoses. A list of words commonly used in discussions of snow metamorphism is presented since these words have often been misused.

Key words: snow, metamorphism, firnification

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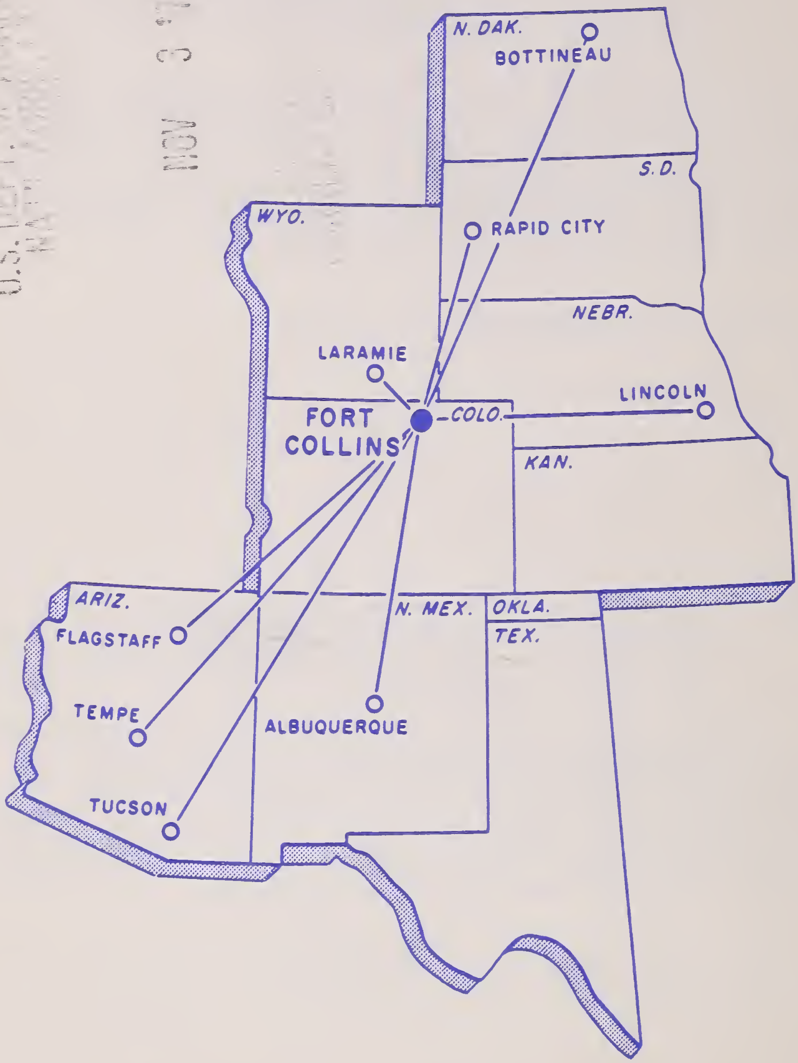
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